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Title: Basics of Radiation Safety

Author(s): Wehmann, Nicholas Karl

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Basics of Radiation Safety

Nicholas Wehmann
LANL Radiation Protection Services

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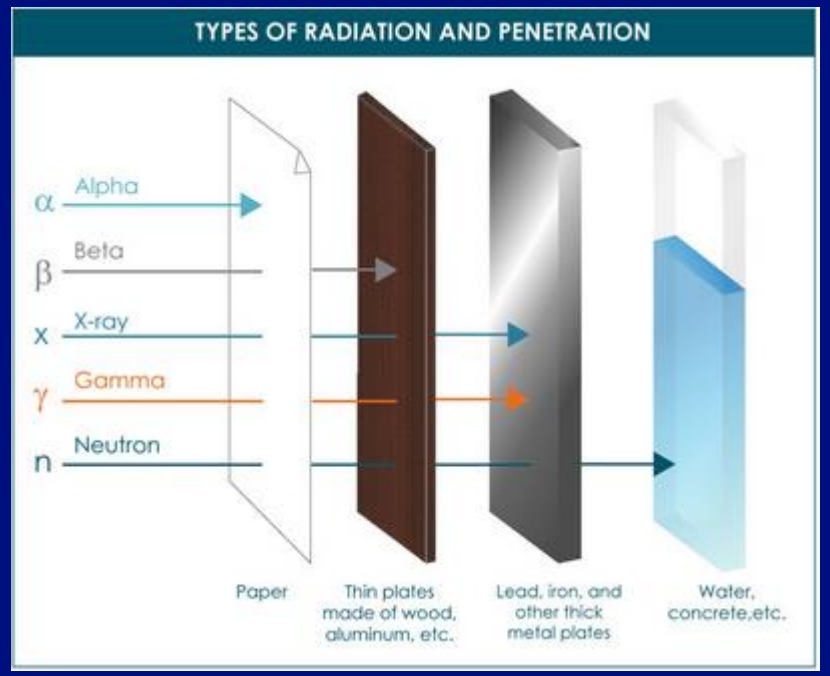
Basics of Radioactive Decay

- Stable vs. Unstable Nuclei
  - Ratio of protons to neutrons in the nucleus
  - If you have too many of either, the nucleus is unstable
- The nucleus ‘wants’ to be stable
- To achieve stability a nucleus will give off energy
  - This is what leads to radiation

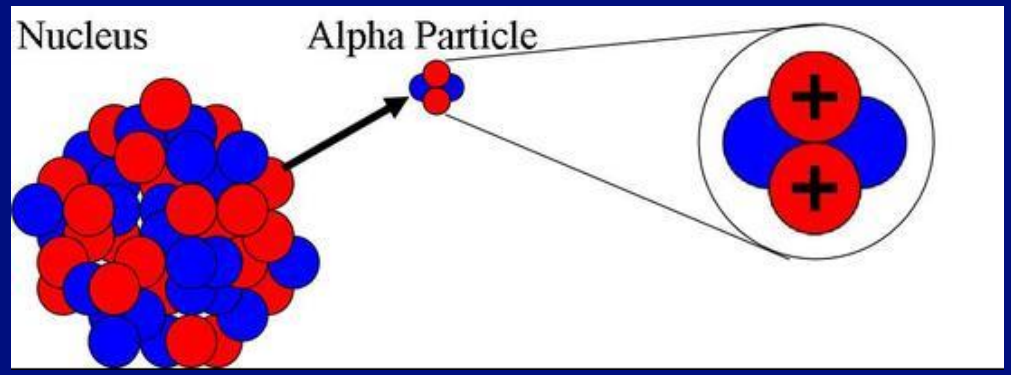
Types of Radiation

- Four main types of radiation
  - Alpha particles
  - Beta particles
  - Gamma/x-rays
  - Neutrons
- Each type has it’s own concerns and mitigations



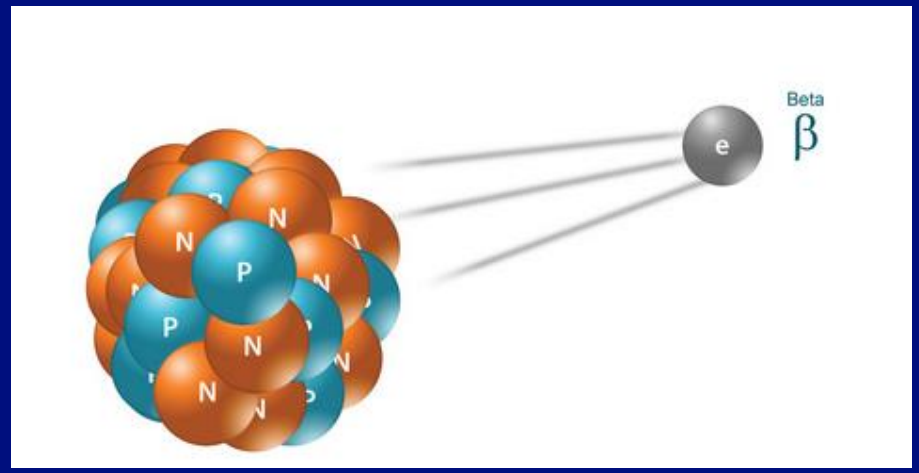
Alpha Radiation

- Alpha decay is the emission of a helium nucleus
- Characteristics of alpha particles:
  - Have a +2 charge
  - Have a (relatively) large mass
- Easily stopped by a piece of paper
- Sources/uses:
  - Am-241 is used in smoke detectors
  - Po-210 is used as a static eliminator
  - Pu-238 is used as a radioisotope thermoelectric generator (RTG) in



Beta Particles

- A beta particle is simply an electron
- Characteristics of beta particles:
  - Have a -1 charge
  - Possess a very small mass
- Beta particles can be stopped by the layer of dead skin
- Sources/uses:
  - Various beta emitters are used for QC of thin materials (paper)
  - Sr-89 & Sr-90 are used to treat eye and bone cancers
  - Tritium (H-3) is used for lighting (emergency exits, night sights on firearms)



Gamma/X-Rays

- Gamma and X-rays are a bit different
  - The only difference between a gamma ray and an x-ray is where it originates.
  - Gammas come from the nucleus, x-rays come from the electron shell.
  - Both can be referred to as “photons”.
- Photon Characteristics:
  - Have no mass and no charge these are just energy
  - It takes lead or something dense to shield these
- Sources/Use:
  - Co-60: sterilization of medical equipment and food stuffs
  - Cs-137: industrial processes, soil moisture-density gauges
  - Am-241: aircraft fuel gauges, fluid levelling and density gauges

Neutrons

- In neutron decay, a neutron is emitted from the nucleus
  - This happens through a few different processes
- Neutron characteristics:
  - Have a neutral charge
  - Are the larges of the subatomic particles
  - Shielding by hydrogenous material
- Sources/Uses
  - AmBe (PuBe, RaBe): used as laboratory neutron generators
    - Anything combined with Be can be assumed to emit neutrons
    - These sources are used in industrial environments as well
  - Cf-252: spontaneous fission source of neutrons
  - Neutron Activation Analysis: used to determine the composition of materials.

Radiation Hazards

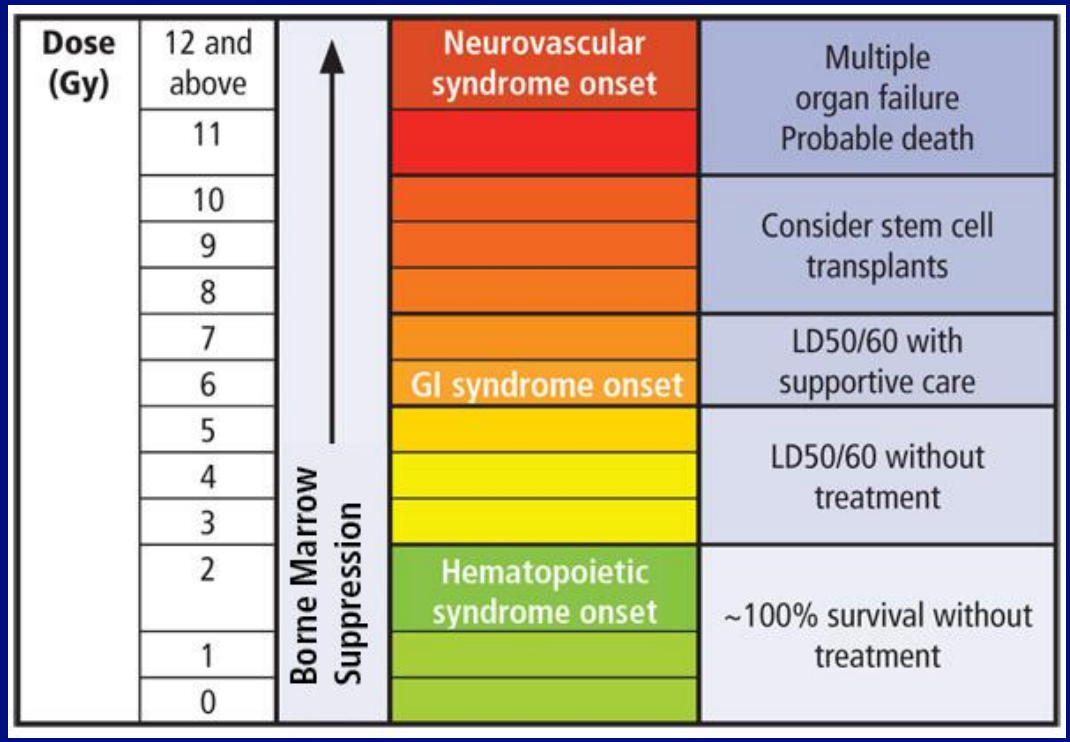
- Alpha particles:
  - Alphas are primarily an internal hazard
  - Range in air is 2-10 centimeters
  - An alpha particle needs 7.5 MeV to penetrate the dead layer of skin
- Beta particles:
  - Primarily internal, can be an external hazard depending on energy and location
  - Range in air is 12 feet/MeV
  - Can induce production of secondary x-rays (Brehmsstrahlung)
  - Beta particles need 70 keV to penetrate the dead layer of skin
    - Can result in “burns” to the skin

Radiation Hazards (cont.)

- Gamma/X-ray
  - Long ranges in air unless shielded
  - Can penetrate the dead layers of skin to deliver dose
    - Can result in “burns” to the skin
  - Requires something very dense (lead) to shield
- Neutrons
  - Can also travel long distances in air
  - Interact preferentially with low Z (density) materials
    - Such as hydrogen, which the human body has plenty of.

Acute Radiation Syndrome

- Three phases to ARS
- Hematopoietic Syndrome:
  - Occurs at doses > 1 Gy (~100R)
  - Not usually significant until 2-3 Gy
  - Impact to bone marrow/cells in the blood
  - Persists for several weeks
  - Medically treatable



Acute Radiation Syndrome (Cont.)

- Gastrointestinal Syndrome
  - Occurs in the higher dose range (>6 Gy)
  - Impacts the rapidly dividing cells of the intestines
  - Symptoms: severe nausea, vomiting, diarrhea
  - Symptoms usually occur within hours of exposure
    - The sooner symptoms occur, the worse the exposure
    - Time to Emesis (TTE) is a common indicator of degree of exposure
  - Can be medically treated, not very effectively
    - Usual outcome is death 8-14 days post accident

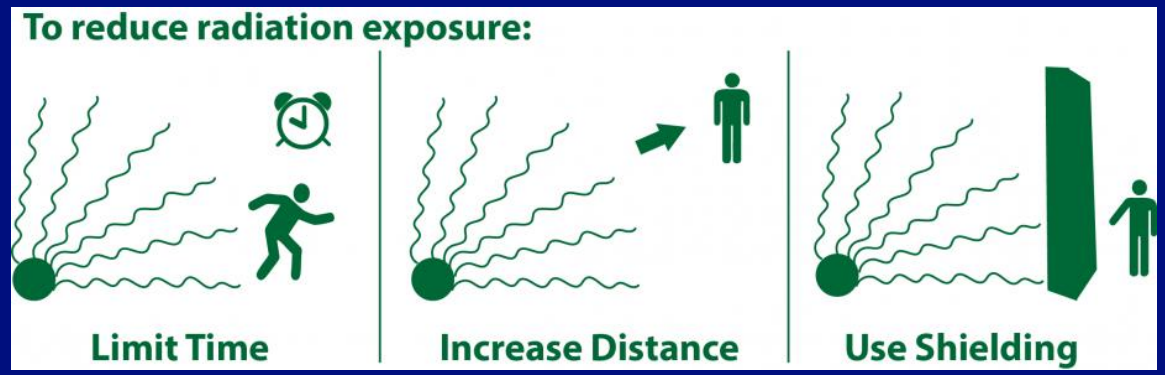
Acute Radiation Syndrome (cont.)

- Neurovascular Syndrome
  - High dose >12 Gy
  - Patient often experiences a burning sensation immediately after exposure, nausea and vomiting within minutes
  - Death is inevitable, usually occurs within 24-48 hours post exposure

Dose (Gy)	% emesis	Median onset of emesis (h)	Absolute lymphocyte count; % of normal in first 24 h	Relative increase in serum amy-lase, day 1	Number of dicentrics per 50 metaphases
0	-	-	100	1	0.05–0.1
1	19	-	88	2	4
2	35	4.6	78	4	12
3	54	2.6	69	6	22
4	72	1.7	60	10	35
5	86	1.3	53	13	51
> 6	90–100	1.0	< 47	> 15	-

Emergency Response Health Physics

- Can get pretty complicated very fast.
- Each type of radiation discussed earlier has it's own hazards.
- Basic concepts to reduce dose:
  - Time, distance, and shielding



Helpful Rules

- There are a few concepts of radiation protection that are incredibly useful to a first responder:
  - $\frac{1}{r^2}$: this describes how radiation intensity decreases the further you are away from the source. If you double your distance, you quarter your dose rate.
  - Generally, after 7 half-lives, an isotope can be considered “gone”
    - This only holds for smaller amounts
  - For an injured person, medical attention ALWAYS takes precedence over contamination concerns.
  - If you’re going to spend extended periods in a radiological environment, find a place with a lower dose rate to wait in

Tips for Radiation Detection

- Radiation detectors are designed to “answer a question”
  - To make sure you are using the correct instrument, think about what question that detector answers
    - Some detectors will tell you dose rate, some will tell you dose rate and identify the isotope
  - There isn’t a single detector that can answer every question
    - There are modifications that can be made to help the detector out, even in the field
      - Use your probe for differentiating gamma and beta radiation
      - Use your body to help determine direction of incoming radiation

Tips for Surveys

- When you are surveying personnel or equipment:
  - Verify you are using the proper instrument before you begin
    - Additionally, try to avoid using equipment you are not familiar with
  - Never touch the person/item directly with the detector probe
    - This may contaminate the probe and throw off all your readings
  - Keep the probe ~1 inch off the item being surveyed
  - Move at a rate of 1-2 inches per second
- For personnel
  - Pay special attention to feet, knees, elbows and hands (most likely to be contaminated)
  - Watch for folds in clothing/protective equipment

Additional Resources

- The Department of Energy maintains several technical teams ready to assist in radiological emergencies:
  - Radiation Emergency Assistance Center/Training Site in Oak Ridge, Tennessee (REAC/TS)
    - Also host virtual and in person radiological trainings
  - Radiological Assistance Program teams based throughout the country (RAP)
  - National Atmospheric Release Advisory Center (NARAC)
  - Accident Response Group (ARG)
  - Other Nuclear Emergency Support Teams (NEST)
    https://www.energy.gov/nnsa/nuclear-emergency-support-team-nest
- Uniformed Services University: Armed Forces Radiobiology Research Institute
  - Deployable Medical Radiobiology Advisory Team (MRAT)
  - Can be deployed independently or as part of DTRA